Low-Cost Metal Roofing

Barn-style metal roofing has moved from hogsheds to houses, but you must pay attention to coatings, substrates, and fasteners

by Rob Haddock

Ag-panels are widely used on house roofs. But because residential roofs are more complicated than the agricultural buildings the roofing was designed for, a builder must use premium metal coatings, factory-finished panels, and watertight details.

Any trip through rural America shows how widespread the use of metal roofing is. You'll see corrugated or ribbed steel panels not only on most barns and outbuildings, but on many houses as well. In recent years, the number of residential metal roofs has increased dramatically, with the popularity of expensive steel, copper, aluminum, and terne standing-seam roof systems. But simple corrugated and ribbed agricultural-style steel and aluminum panels are increasingly being used on houses because they provide a reasonably priced, long-lasting, low-maintenance roof.

Panel manufacturers, however, are reluctant to acknowledge that agricultural-type roof panels can be used for residential roofs. In many cases the manufacturer will steer a house builder to more elaborate roofing systems. Consequently, the budget-minded builder who opts to use ag-panels may not find good technical support. This article will attempt to fill that void, describing how to select agricultural-style roof panels for use on houses, and how to specify substrates and fasteners.

Ag-Panels

Agricultural-style panels have evolved from corrugated steel sheets coated with molten zinc to aluminum- and alloy-coated panels that mimic the look of true standing-seam roofing. But while the look may be similar, ag-panels differ from standing-seam roof systems in several important ways.

First, the panel ribs in an ag-panel are formed shapes of various geometries, rather than folded seams (see Figure 1, next page). The ribs may be continuous waves, as on the old-style corrugated roofing, or they may be spaced apart by flat sections of panel. This formed profile creates problems where panels are cut diagonally, particularly in valleys. The cut exposes voids just where water protection is needed most.

Second, ag-panels are secured by an exposed fastener — usually a screw with a rubber gasket — through the face of the panel. The fastener is exposed to weather and stressed by thermal movement of the panel, so it should be inspected periodically to safeguard against water penetration.

In addition, ag-panels are usually made of lighter gauge steel (typically 29 gauge) than standing-seam roofing and have lower ribs that are closer together. The ribs of an ag-panel are typically 1/2 to 7/8 inch tall and are spaced about 6 or 9 inches apart.

Water Shed vs. Watertight

Agricultural buildings are simple in design and, in most cases, simple "water shedding" techniques will work to keep the building dry. That is, roof slopes are typically steep enough that rain water and snowmelt run right off. And the buildings are usually uninsulated, so snow melts evenly. Thus roof panels can simply be lapped without sealants. And if the water does back up occasionally, the consequences aren't terrible since there are no finished ceilings to worry about.

Houses are different. Residential roof geometries are usually more complex — involving slope transitions, dormers, and valleys — and have a lot of roof penetrations, such as chimneys, flues, and plumbing vents. These details hold snow longer and have greater potential for leaks.

To combat this, a builder must select metal panels with premium metallic coatings and use watertight detailing (see "For More Information," at end of article).

Metallic Coatings on Steel

All sheet steel used for roofing is coated with a thin layer of corrosion-resistant metal. This coating is applied at temperatures in excess of 1,300°F and is metallurgically bonded to the base steel sheet. There are three coating options available: zinc, aluminum, and an alloy containing both.

Zinc. Pure zinc coatings, commonly known as *galvanized*, have been used since the turn of the century. Common designations for roof panels are G-60 and G-90. The "60" and "90" are minimum application rates of the coating equal to .60 and .90 ounces of zinc per square foot (total both sides).

Zinc is considered a sacrificial coating. It slowly oxidizes to protect the base steel from corrosion. Zinc can actually "heal" exposed cut edges and scratches in its surface because it is somewhat water soluble. Water will dissolve the coating and redeposit a small amount on the exposed surfaces, providing some measure of protection. These same characteristics, however, also mean that the life of the coating depends on its thickness and how much moisture it is exposed to. When all the zinc is oxidized, the base steel begins to rust.

Standing-Seam vs. Agricultural Panels

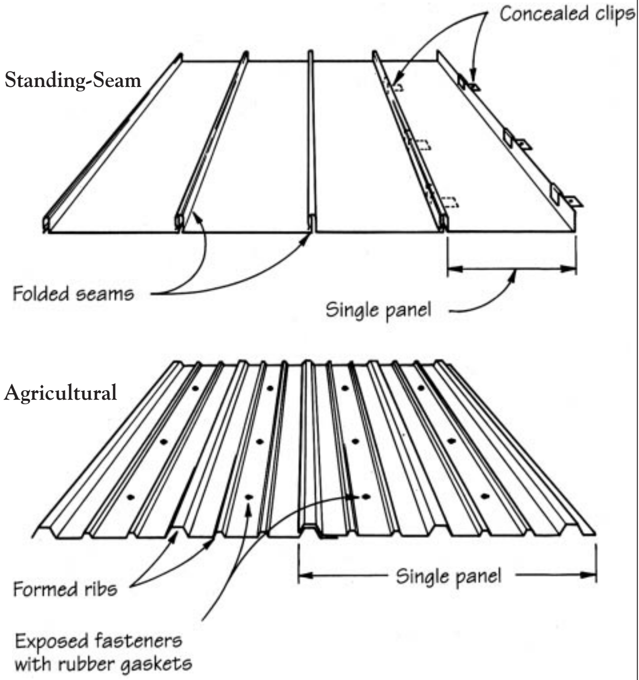

Figure 1. *Standing-seam roof systems (top) have folded seams and are fastened by concealed clips. By contrast, agricultural-style metal panels (above) have formed ribs spaced by flat sections and exposed fasteners.*

On steep roofs in dry climates, unpainted galvanized steel can last 30 years and longer. On low-slope roofs in wet climates, signs of coating loss and base-sheet corrosion may occur within five years.

Aluminum. Pure aluminum coatings on sheet steel are known as *Aluminized* coatings. Aluminized panels for roofing have a "Type II" designation. ("Type I" is only used in the automotive industry.)

Aluminized Type II is considered a premium coating when compared to galvanized. Aluminum is inert and provides a true barrier rather than sacrificial protection. It is, therefore, a longer lasting coating. Aluminized panels are typically warranted for 20 years against corrosion failure in normal environments, even at slopes as low as 1/4 in 12.

Aluminum-zinc alloys. An aluminum-zinc (AlZn) alloy coating known as G*alvalume* takes advantage of the healing characteristics of zinc, melded with the barrier protection of aluminum. The typical coating weight is designated AZ-55 (.55 oz./sq.ft. — total both sides). This alloy is 55% aluminum to 45% zinc, by weight. Because Galvalume combines the advantages of both materials, the manufacturers claim that it has greater corrosion resistance than an Aluminized coating. Field exposure testing and analysis show that this coating can be expected to significantly outlive its warranted life of 20 years, even on low-slope roofs.

Unpainted panels. Many roof panels use one of these coatings without an additional paint finish. At first glance, all the bare coatings look similar, but upon closer inspection, they can be identified by their appearance. Galvanized panels have a bold "spangle" appearance — the zinc looks like large metallic flakes. Galvalume has a much smaller spangle; you have to look closely to see the metallic flakes. Both of these materials are highly reflective (glossy), but will weather to a dull gray within a few years. Aluminized starts out with a matte silver-gray appearance with no spangle and loses gloss over time.

While a homeowner is often willing to spend the additional 5¢ or so per square foot it costs to upgrade to an Aluminized or alloy coating, many agricultural-type panels are not available with the premium finishes.

Solid Aluminum Panels

Aluminum ag-panels are a step above the coated-steel panels because they offer superior corrosion resistance. However, aluminum panels have a much higher coefficient of expansion than steel, so they are more likely to expand and contract due to temperature differences (more on this below).

Aluminum ag-panels are typically available in sheet thicknesses between .015 and .02 inches. This is considerably thinner than the common commercial aluminum panel thickness of .032 inches. Commercial panels, however, usually span 5-feet or more on roofs. Ag-panels, on the other hand, can span only about 30-inches or less between purlins or sleepers. Check with the panel manufacturer for the maximum purlin spacing allowed for a panel.

Limitations of Metal

Metal roofing is subject to galvanic action. Aluminum panels and all the metallic coatings on steel panels are "anodic" in behavior, meaning they will degrade when in contact with metals that are closer to the "cathodic" end of the galvanic scale (see Figure 2). Therefore, care should be taken to shield cathodic metal flashings from the roof panels. Even rain water dripping from a copper flashing can seriously corrode the metallic coating of a roof panel.

If an evaporative cooler is in a place where it might drip condensate from copper lines onto the roof, the condensate must be isolated from the roof panels. Consider using a drip pan under the unit drained by a PVC pipe to the eaves. If the house has existing copper gutters, they can be left in place as long as they do not come in contact with the metal panels. Be sure that the gutters are separated at the eaves by furring, roofing felts, or existing composition roofing. However, in the case of a multi-level roof where water from a copper gutter can drip onto a lower roof, you should replace the gutter.

Graphite can also corrode the metallic coatings. Don't use a pencil to mark cuts and fastener layouts. Instead, use a felt-tipped marker.

Aluminum panels and coatings must also be protected from wet mortar, which is very alkaline and will corrode the aluminum surface rapidly, leaving black stains and eventually an exposed steel sheet (see Figure 3). When repairing brick parapet walls, end walls, or chimneys, take care to protect premium steel coatings by scheduling the work before installing the roof, or by laying down plywood and tarps. Never use premium-coated steel for reglet flashings (flashings that are embedded in masonry joints), unless the coated steel is first sprayed with acrylic or lacquer finish to protect the coating until the mortar is fully cured. Once the mortar is dry, however, it no longer poses a threat.

A final note of caution: Metallic-coated panels have a weakness to salt spray. Although they have proven quite durable in the presence of many industrial pollutants, salt will accelerate corrosion and significantly diminish the life of a panel. A coastal house with a premium metallic-coated roof can show signs of corrosion within five to seven years, depending on the level of exposure to salt spray. Using silicon-modified polyester paint will improve life expectancy to a degree (see "Paint for Metal Roofs").

Galvanic Scale

Anodic

Zinc
Aluminum
Steel
Cast iron
Lead
Tin
Brasses
Copper
Stainless (passive)
Graphite

Cathodic

Figure 2. *Take care to shield metal panels at the anodic end of the scale from fasteners and flashings at the cathodic end. The more distant one metal is from another, the more rapid and severe the corrosion will be. Note that, although stainless steel is at the cathodic end, it is considered "passive," meaning it is unreactive.*

Factory Paint Vs. Field-Applied Paint

The notion of field painting is not only archaic from a quality standpoint, but it is also extremely expensive when compared with factory finishes. With lower-grade paints, or improper preparation, the finish may not even last two years. Even the highest quality field application can be expected to last only five to seven years (see Figure 4).

A good factory finish, on the other hand, can add considerably to a panel's lifetime. All the metallic-coated panels discussed above can be finish-coated by means of a "coil coating" process. The metal-coated steel coil is generally shipped directly to the coil coater where it is fed through a series of machines that clean and degrease, preheat, prime, dry, finish coat, dry, and recoil for shipment to the panel manufacturer. This results in a very durable paint finish that is typically warranted against chipping, cracking, blistering, peeling, fading, and chalking for various periods of time, depending on the quality of the paints used.

Even factory finishes, however, will not protect steel indefinitely. The life of a factory paint depends on the stability of the pigment, and the quality of the resin. Because the agricultural industry is so economy minded, ag-panels are usually coated with the most inexpensive paint — one with a polyester resin. While most folks don't mind if their barn roof fades, they probably won't appreciate this on their house. Check with the panel supplier to see what paint options are available. Some may have a good-quality silicon-modified polyester resin finish. Few, if any, will offer the best quality fluoropolymer-resin finishes, except on heavier-gauge premium commercial products.

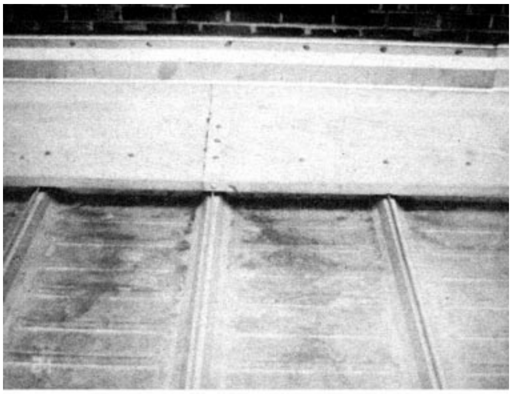

Figure 3. *The stains and corrosion on these aluminum-coated panels are the result of wet mortar that spilled while repointing the end wall. Care should have been taken to protect the panels with plywood or tarps. Dry mortar, however, poses no threat.*

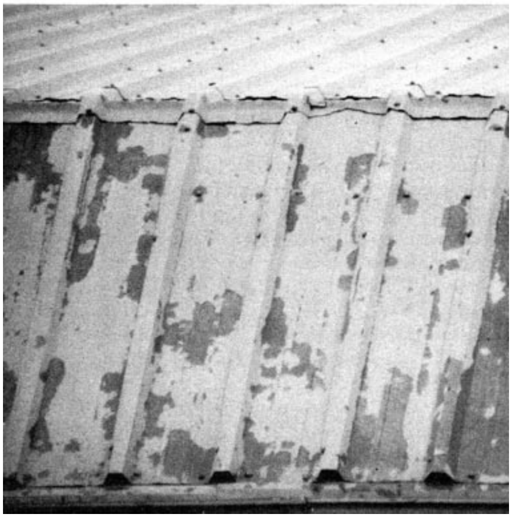

Figure 4. *A field-applied paint, such as the coating on this metal roof, can be expected to last only five to seven years. High-quality factory-coated panels, however, can last over 20 years.*

When faced with a choice of using polyester or nothing at all, seriously consider the "nothing at all" option. A bare Aluminized or Galvalume panel is a maintenance-free option in most environments for 40 years or more on slopes of 1:12 or greater. An inexpensive polyester finish, on the other hand, can severely fade within seven years and will need repainting. Thus, choosing an inexpensive finish will lock the homeowner into repeated and perpetual maintenance. If the look of the bare material is not highly objectionable, it is a better route to go in the long run, and it costs less initially. If objections to a bare metallic finish are high, suggest using prepainted white material, which is not subject to fading or noticeable chalking. White usually costs less than colored finishes, as well, and because it is more reflective, it will be less prone to thermal expansion.

Thermal Response

Since most metal roof panels have some sort of corrugation, thermal movement of the panel across its width is easily accommodated by flexing within the ribs. Thermal movement along the length of the panel, however, can cause a number of problems, some of which lead to roof failure.

The amount of thermal movement in a roof panel is determined by two factors, which vary from job to job. One is the unbroken length of the panel. The longer the panel, the more the panel will move. The other is the range of surface temperatures on the panel. The greater the range, the greater the movement.

The surface temperature of a panel is affected by panel color and climate. A dark colored panel can easily be 80°F hotter than the air temperature on a bright sunny day. A pure white panel, on the other hand, may only be a few degrees warmer than the air.

The surface temperature of a dark colored panel can reach up to 180°F or more, and can dip below the ambient air on a clear night, due to radiational cooling (this is why you will often see frost on a metal roof, even when the air temperature is well above freezing.) In some climates, the surface temperature of the roof can range from 180° to -40°, a difference of 220°F. In this case, a 30-foot-long panel will move over 1/2 an inch (see "Calculating Thermal Response," next page).

In more temperate climates the difference may be only 160°F, and if we change the panel color to white it may be reduced to 100°F. In this case, the 30-foot-long panel will only move about 1/4 inch. If you are using an aluminum panel rather than steel, however, the movement

Paint for Metal Roofs

All roof paints are composed of three primary ingredients: the pigment, the solvent, and the resin. The pigment is the particles of color that are suspended in and protected by the resin. The solvent is the vehicle that transports the pigment to the panel surface, and the resin (also known as the binder) is the "glue" that holds it there for years to come. Once the paint has cured and the solvent has evaporated, the resin surrounds the pigment particles, protecting them from moisture and atmospheric pollutants. If properly applied, a good paint will stay on a metal panel for 30 years or longer without cracking, blistering, and peeling. When we ask how long paint will last, we are really asking how long it will retain its color. The answer to this lies in the stability of the pigment and the quality of the resin.

Pigments

Some colors are less stable and will fade more rapidly than others. Bright red is probably the worst. Generally speaking, the "cleaner" the color — that is, the closer it is to a primary color — the more rapidly and drastically it will fade. When possible, it is best to select a color that is toned down a bit. For instance, if the customer wants red, suggest a brick red, rather than a fire engine red. Contrary to popular belief, the tendency to fade has more to do with the "cleanness" of the color than the shade. Darker shades are no more likely to fade than lighter, as long as the color is not too "clean."

In addition, some pigments are more stable than others, and hence, less likely to fade. In general, the more expensive, inorganic pigments are used with the more expensive resins to produce the best paints. The less stable pigments are used with cheaper resins in low-quality paints.

Resins

Chalking is the degradation of paint resins by ultraviolet light. As a resin turns to powder, the pigments are exposed and fading is accelerated.

There are many different resins, and all have different weathering characteristics. The three most commonly used resins on building panels are polyester, silicon-modified polyester, and fluoropolymer based.

Polyester resins are widely used because of their low cost, and are available in every color of the rainbow. They will usually have a medium gloss when new, but this gloss will not last very long. Polyester resin paints are rarely warranted for gloss retention, fade, and chalk. If they are, one should be careful to read the "fine print," because their performance in these areas is very limited. For example, it is not at all unusual for a bright red polyester on a southern exposure to fade to pink within five to seven years, or a medium blue to fade to sky blue within a few years more. Severe fading is rarely uniform, so the effect is very unsightly.

Silicon-modified polyester resins have different blends of polyester and silicon additives, which improve the performance of the resin. Generally speaking, the higher the silicon content, the better the performance life of the paint. Silicon-modified polyester formulations are generally glossy in appearance and will retain the gloss for much longer periods of time than polyesters. Some formulations are available with 20-year warranties against *excessive* chalk and fade. This is qualified because there is no such thing as an unconditional warranty against fade. All pigments will fade over time, some more than others. The warranty simply covers fade beyond a certain level for a certain period of time. Silicon-modified polyester is usually about 6¢ to 12¢ per square foot more expensive than polyester.

Fluoropolymer resins are the state of the art in today's resin technology. They use a material known as Kynar or Hylar, typically in a 70% formulation. This technology has been licensed to five paint companies who manufacture paints known by the trade names Duranar, Nubelar, Fluropon, Trinar, and Visulure. The chemical formulation of this resin makes it a close cousin to Teflon.

Fluoropolymer resin paints typically have a 20-year warranty against excessive fade and chalk. They have a low gloss and are not usually available in bright, clean colors because of the unstable nature of those pigments. Fluoropolymer resin paints are widely used in commercial and architectural applications and are significantly more expensive than polyesters, usually by 15¢ to 25¢ per square foot.

— R. H.

Thermal Response Over Steel Purlins

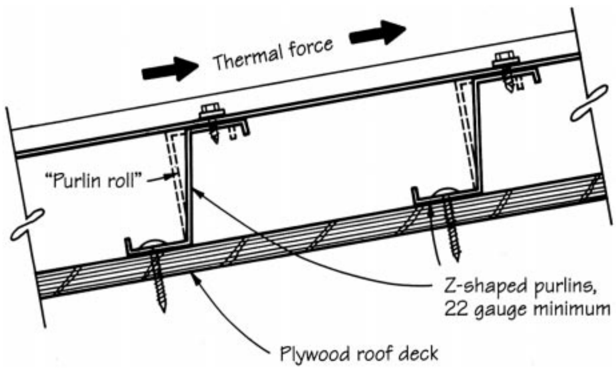

Figure 5. *When metal roof panels are installed over 2-inch-high Z-shaped metal sleepers, thermal expansion of the panels is absorbed by "purlin roll."*

will almost double because of aluminum's higher coefficient of expansion.

Panel Movement

Thermal movement can be accommodated by the roof construction. If the panels are installed over wood or steel purlins, as they are on a typical barn roof, the purlins will deflect and rotate slightly as the panels expand and contract, causing little or no harm to the roof system. However, if the panels are installed over solid plywood, as they are on most houses, the thermal response of the same panels will be much different. A plywood deck does not rotate and deflect as a purlin does, and so the panel will tend to bow or "crown" slightly between fasteners. As the panel crowns, it exerts great force on the fasteners. In fact, a 30-foot-long panel (29-gauge, 3-foot covering width) can generate over 13 tons of force by thermal movement. Adding more screws to resist the panel movement is not the answer. Over time, some sort of fatigue will occur.

Attachment fatigue can happen in one of two ways, or a combination of both:

First, the *panel* can fatigue. If the screw is driven into a good solid substrate, the panel will move relative to the screw, elongating the screw hole in the panel. The hole does not usually elongate enough to become exposed, but repeated movement will fatigue the rubber gasket on the screw until leaks begin. While the goal is to avoid this failure, you should advise the homeowner to visually inspect the fastener seals on the roof every few years. Don't let him wait until water is dripping on the floor. By that time the deck may be rotten and the roof panels corroded from the inside out.

Second, the *substrate* can fatigue. If the screw is not deeply anchored in solid wood, panel movement can force the screw to pivot back and forth. This enlarges the fastener hole in the deck and decreases the thread engagement. This is a more serious failure, and can lead to a roof blow-off.

Which type of fatigue occurs usually reflects the "weak link" in the roof. Aluminum or lightweight steel panels, for example, tend to fail at the fastener hole. Heavier-gauge panels can resist this type of fatigue, but the substrate may be the weak link. The only way to avoid either type of fatigue is to install metal panels over 2-inch-high Z-shaped metal sleepers. Over a solid deck, these sleepers will accommodate the thermal response of a panel (see Figure 5). Wood or "hat-shaped" metal sleepers over a solid deck do not flex adequately.

Most textbook engineers advise against ever installing metal panels directly onto a solid deck. However, installing the panels over purlins or sleepers isn't always practical, especially if you are facing a reroof over an existing solid deck and have a limited budget. In such cases, follow these guidelines to help prevent attachment failures:

- Stick to shorter panel lengths. It may be wiser to walk away from a job where the owner wants a 40-foot slope covered with one unbroken panel than to run the risk of roof failure.
- Encourage the use of white whenever possible, especially when using longer panel lengths. Lighter shades of color will also help.
- Use a good washered wood screw in the flat of the panel, *not* in the high rib, and *never* use nails. Select a screw long enough to pierce all the way through the deck plus 1/4 to 1/2 inch.
- Increase the spacing of fastener rows along the panel length, and decrease it along the panel width. This will cause more panel crowning between fastener rows, which is preferable to attachment fatigue. Do not, however, exceed 5 to 6 feet between rows, as wind uplift resistance can get dangerously low. Check this with the panel supplier, since this characteristic varies from one panel style to the next.
- When using aluminum panels, the movement will almost double, usually causing elongation of the fastener hole in the panel. Also, the tensile strength of aluminum is much lower than steel. Using long lengths of aluminum sheet may cause the elongated hole to exceed the size of the washer. This spells L-E-A-K. ■

Rob Haddock is the director of the Metal Roof Advisory Group in Colorado Springs, Colo., and a former roofing contractor with over 20 years experience.

Calculating Thermal Response

To get an accurate measurement of how much a metal panel will move in any climate, use the formula:

$$\Delta L = \Delta T \times L \times Ce$$

ΔL is the change in length of the panel.
ΔT is the change in surface temperature throughout the year (in °F).
L is the panel length (in inches).
Ce is the coefficient of expansion for the panel material (see list below).

For example, in a climate where the surface temperature change is 220°F, a 30-foot steel panel will move about 1/2 inch (220°F x 360 in. x .0000067 = .53 inches).

Coefficients of Expansion for Metal Roofs

Steel	.0000067
Copper	.0000094
Aluminum	.0000129
Stainless	.0000096

— R. H.

For More Information

There are very few standards for metal roofing, and most of the information available on installing panels is limited to metal building construction. There is almost nothing about achieving the watertight details that are necessary for complex residential roofs. For detailed information on sealing and flashing metal panels, send a self-addressed stamped envelope to Metal Roofs, RR2, Box 146, Richmond, VT 05477.